

STATE OF AIR QUALITY IN AND OUTSIDE OF HOSPITAL WARDS IN URBAN CENTRES – A CASE STUDY IN LAHORE, PAKISTAN

T. Gulshan¹, Z. Ali^{1*}, Z. Zona¹, B. Ansari¹, M. Ahmad¹, I. Zainab¹, Z. A. Nasir^{2,3} and I. Colbeck³

¹Environmental Health and Wildlife, Department of Zoology, University of the Punjab, Lahore, Pakistan

²School of Energy, Environment and Agrifood, Cranfield University, Cranfield, Bedfordshire MK43 0AL, UK

³School of Biological Sciences, University of Essex, Colchester, Essex, CO4 3SQ, UK

*Corresponding Author's Email: zali.zool@pu.edu.pk

ABSTRACT

Particulate pollution in healthcare facilities is a potential threat to healthcare workers, patients and visitors. A study was carried out to monitor particulate levels in and outside of five wards of Sheikh Zayed Hospital, a tertiary healthcare facility of Lahore. Measurements indicated that the hourly mean concentrations of PM_{2.5} in a medical, pulmonology (chest), surgical, pediatric and nephrology ward were 78 ± 37 , 86 ± 46 , 94 ± 48 , 169 ± 122 and $488 \pm 314 \mu\text{g m}^{-3}$ respectively. The outside levels of PM_{2.5} of the same wards were 69 ± 27 , 81 ± 49 , 178 ± 85 , 282 ± 164 and $421 \pm 240 \mu\text{g m}^{-3}$. Indoor levels were higher than outdoors in all the wards except surgical and pediatric ward. Such elevated levels of PM can result in aggravation of the poor health status of the patients as well as affecting the hospital staff and visitors.

Keywords: Particulate matter, hospital, wards, outdoor, Pakistan.

INTRODUCTION

Nosocomial outbreaks have been associated with airborne transmission and role of microorganisms in aerosolized form in hospital acquired infection is thought to be much greater than is up to now recognized. Immuno-compromised patients have also higher risk of becoming infected. Furthermore, epidemiological studies demonstrate associations between particulate matter (PM) concentrations and increased morbidity and mortality; while toxicological studies have begun to provide potential biological explanations for these observed associations. Previous studies have revealed the significance of indoor air quality and of the contribution of indoor sources to particle concentrations. The quality of air in the indoor hospital environment is of increasing concern both for patients and healthcare personnel who are exposed to infectious microorganisms and particulate matter. Additionally, healthcare staff are also prone to healthcare associated infections (HCAIs) due to their interaction and proximity to infectious sources. The problem regards not only medical equipment and the cleanliness of the staff but also surfaces in rooms and indoor air. (Charkowska, 2008).

In general, HCAIs are spread by contact, however, there is growing evidence that an airborne route has played a major role in nosocomial outbreaks of many pathogens e.g. *Staphylococcus aureus*, *Acinetobacter* spp and *Serratia marcescens* (Uduman *et al.* 2002; Kumari *et al.* 1998; Bernards *et al.* 1998). Additionally, infection transmission by deposition and/or resuspension is also an important pathways. It can be argued that the state of air

quality in hospitals, particularly with reference to particulate matter, is likely to impact on HCAIs.

Many air pollutants are present in the air but most important is particulate matter which is responsible for cardio-vascular ailments (Pope *et al.* 1995). Concentrations of particulate matter indoors depend upon the various indoor sources/activities (e.g. cleaning, dusting and sweeping and poor ventilation) and also on outdoor sources and seasonal variations (Nitta *et al.* 1994; Abt *et al.* 2000). Air borne particles in hospitals are of vital concern for infection control to protect hospital workforces and patients. Infectious agents in aerosols may be spread by droplet nuclei, aerial and unclean surfaces. Prospective health effects of particulate matter in hospital air are many including toxic, allergenic and infectious. In fact, every hospital has an inherent risk of HCAIs, however, the burden is higher in developing countries in comparison to developed with a prevalence of 10% (WHO 2011). Furthermore, developing countries are facing excessive levels of particulate matter, especially, in urban centres and these are very likely to contribute to indoor level of particulate matter in hospitals in these areas. Additionally, administrative, engineering and personal control measures to reduce the risk of exposure to airborne hazards in hospitals are often minimal in these countries.

The current research was undertaken to monitor ambient and indoor PM_{2.5} levels, simultaneously, in five different wards of Sheikh Zayed Hospital in Lahore, Pakistan as a case study to comprehend the impact of ambient PM on indoors as well as to gauge the effectiveness of existing protection measures.

MATERIALS AND METHODS

Study site: Sheikh Zayed Hospital is a tertiary care hospital located in Lahore (31° 30'N and 74° 18'E), Punjab Pakistan (Figure 1). It was established in 1986

and is consisting of 99 wards and 713 beds. About 50,000 patients visit the hospital annually. Table 1 provides a summary of the selected wards in the Sheikh Zayed Hospital.



Figure 1: Location of Sheikh Zayed Hospital, Lahore

Table 1. Characteristics of the selected wards

Parameters	Medical ward	Pulmonary ward	Surgical ward	Pediatrics ward	Nephrology ward
Ward size	39m ²	39m ²	39m ²	39m ²	39m ²
Number of beds	6	6	6	8	8
Beds occupied	4	6	5	8	7
Number of windows	2	2	2	2	3
Windows closed/open	Closed	Closed	Closed	Closed	Closed
Number of visitors	9	10	9	14	17
Activities in the ward	Monitoring of vitals, running medication, people movement, dinning practices, doctor's visit	Monitoring of vitals, running medication, people movement, dinning practices, doctor's visit	Preoperative and post-operative care, Administering medication by nurses, people movement, dinning practices, doctor's visit	Administering medication by nurses, people movement, dinning practices, doctor's visit	Administering medication by nurses, people movement, dinning practices, doctor's visit
Ventilation	By door	By door	By door	By door	By door

Monitoring of ambient and indoor PM_{2.5} levels: PM_{2.5} was sampled by using a real time aerosol monitoring instrument, DustTrak (TSI Model 8520). Two DustTrak monitors were run in parallel, one inside the ward and the other running simultaneously just outside the hospital.

The sampling duration for each ward (indoor and ambient) was 24 hours. Ambient air was sampled relative to each ward and the sampler was placed on the roof of the ward. Average concentrations of all the sampling sites were obtained. Different activities in the wards were also noted. The association between indoor (ward) air and ambient air was statistically tested by

applying correlation bivariate analysis using SPSS version (17) with a significance level of 0.01.

RESULTS AND DISCUSSION

The latitude of this work was to characterize PM_{2.5} in different wards (Medical, Pulmonology, Surgical, Pediatrics and Nephrology) of patients in hospital microenvironment and to examine the relative contribution of indoor and outdoor sources to PM_{2.5} in different wards (Table -2).

Table 2. Summary of PM_{2.5} concentration in different wards

PM _{2.5} hourly mean and standard deviation at the study site			
Wards	Hourly Mean	SD	I/O ratio
Medical ward	78	±37	1.130
Medical ward outdoor	69	±27	
Pulmonary ward	86	±46	1.061
Pulmonary ward outdoor	81	±49	
Surgical ward	94	±48	0.528
Surgical ward out door	178	±85	
Pediatrics ward	169	±122	0.600
Pediatrics ward outdoor	282	±164	
Nephrology ward	488	±314	1.159
Nephrology ward outdoor	421	±240	

The indoor to outdoor PM ratio of five different wards i.e. medical, pulmonology, surgical, pediatrics and nephrology was observed to be 1.13, 1.06, 0.53, 0.60 and 1.16 respectively. The highest I/O ratio was found in the nephrology ward. This has the largest number of visitors, along with varied activities. The differences among the wards results from the geometry of the cracks in buildings, indoor particle sources, outdoor environments and ventilation patterns. Different indoor activities largely influence the levels of indoor PM. It was noted that although peaks were recorded in the ambient air during high vehicular activity, in most cases the levels were generally lower than those recorded in the indoor environment. The impact of ambient PM_{2.5} levels on the indoor air quality is also clearly indicated in the comparative graphs given. It is evident that although the hospital is centrally air conditioned, the wards are not air-tight thereby allowing infiltration from the outside mainly by doors. Such infiltration is an important contributing

factor in defining the indoor air quality and this situation can cause multiple health effects.

With reference to medical ward the highest levels of PM_{2.5} occurred during the hours when there was a doctor's visit, dinner time and prayer time as shown in Figure 2. For the pulmonology ward (Figure 3) the highest levels of PM_{2.5} occurred during the hours when there was heavy traffic load. As the hospital is situated in an urban area on a busy road, traffic emission are major source of PM_{2.5}. Other activities including a doctor's visit and dining times show increases in PM concentrations. Peak concentrations of PM_{2.5} were seen during heavy traffic which indicates the infiltration of particulate matter from outside. Different indoor activities and outdoor sources were main contributor to increased PM concentrations in the surgical wards as well (Figure 4).

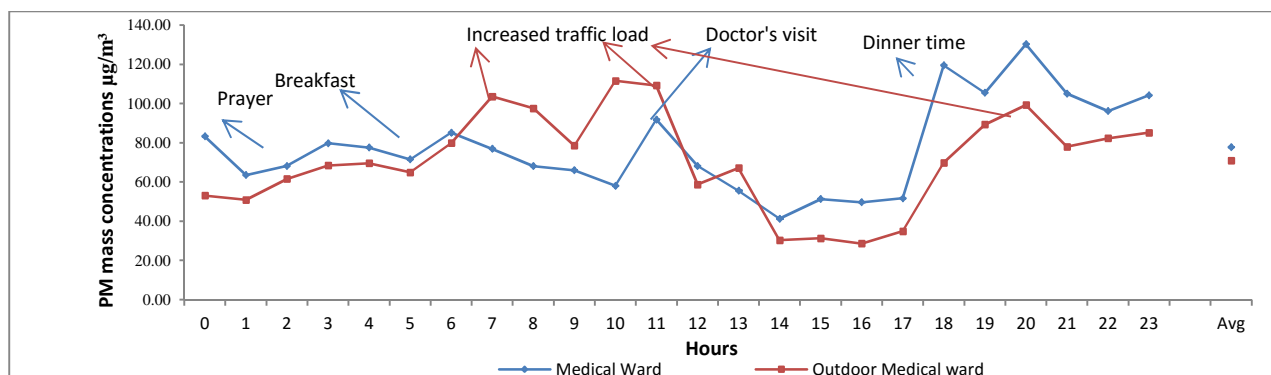


Figure 2: PM_{2.5} levels in Medical ward and outdoor resulting from various activities

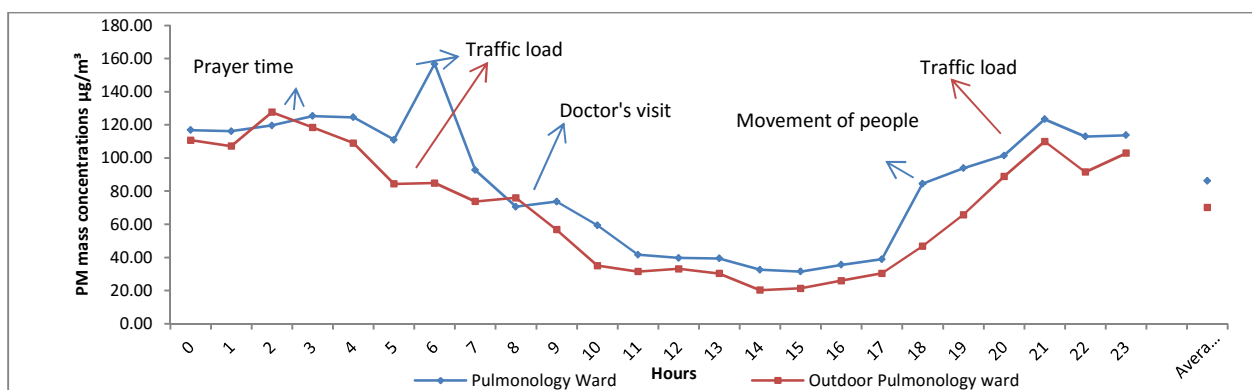


Figure 3: PM_{2.5} levels in pulmonary ward and outdoor resulting from various activities

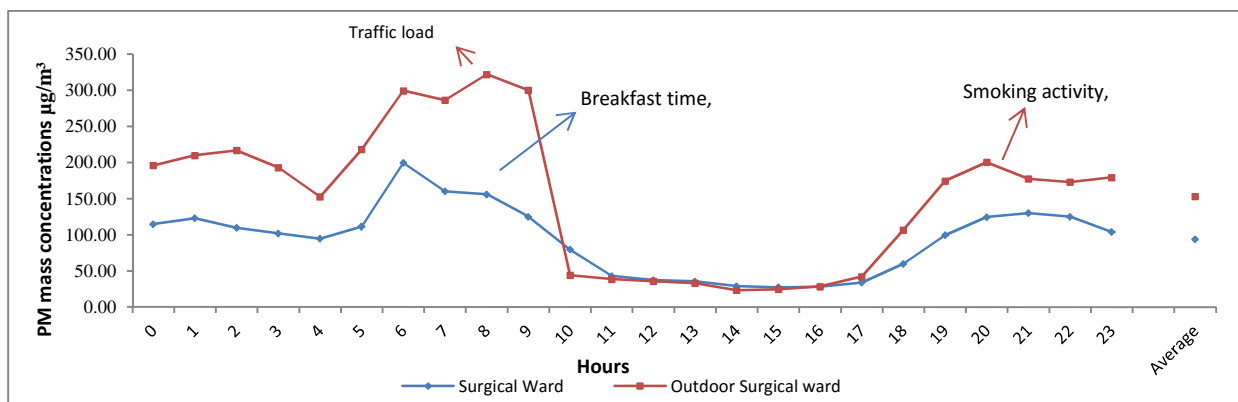


Figure 4: PM_{2.5} levels in surgical ward and outdoor resulting from various activities

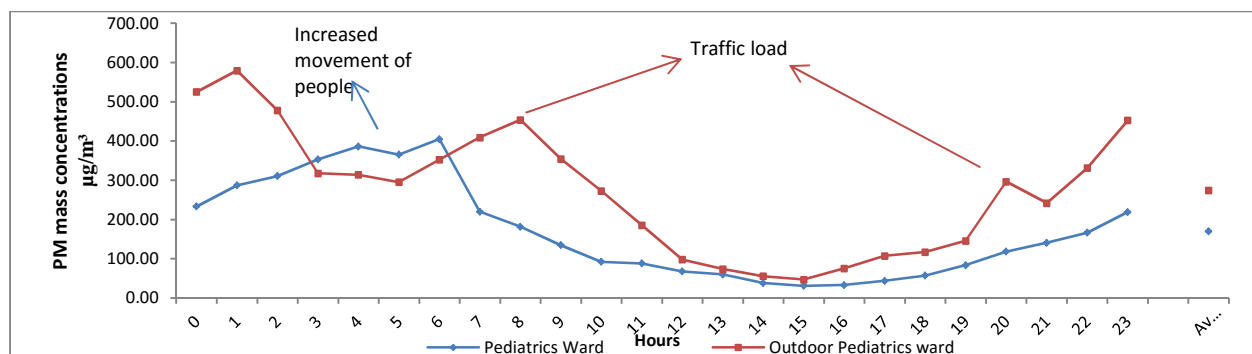


Figure 5: PM_{2.5} levels in Pediatric ward and outdoor resulting from various activities

Increased levels of $PM_{2.5}$ were observed in the pediatrics ward during visiting hours where the movement of people causes re-suspension of the pollutant

as shown in Figure 5. In addition this ward is not air conditioned and is equipped with 8 fans which, when on, cause high rates of particulate matter re-suspension.

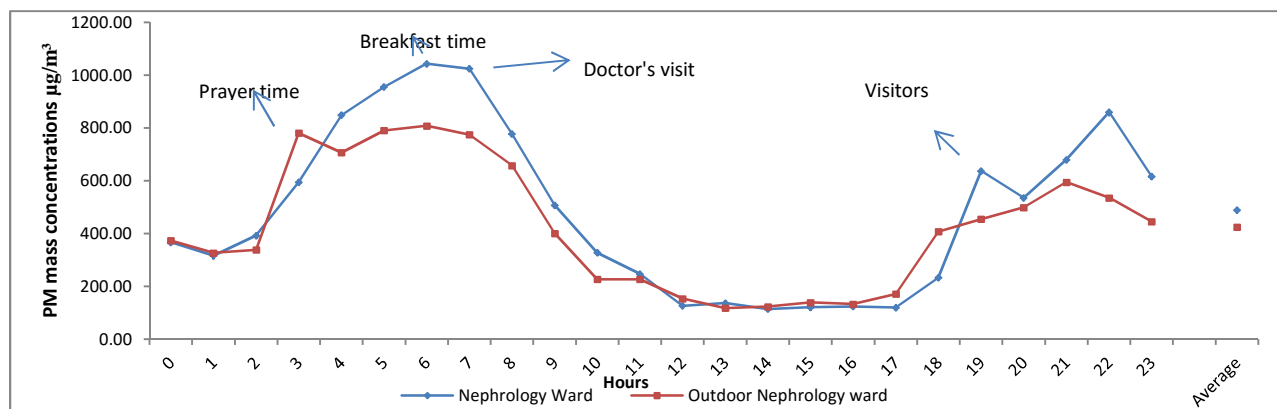


Figure 6: $PM_{2.5}$ levels in and out of Nephrology ward resulting from various activities

Similar results were obtained in the nephrology ward as shown in Figure 6. A statistically significant positive correlation was observed between the wards (indoor air) and ambient air with an alpha value of 0.01 being used. The obtained p values were 0.00, 0.001, 0.00, 0.006, 0.000 for medical, pulmonary, surgical, and paediatric and nephrology ward respectively.

Apart from outdoor air influencing the indoor air, multiple indoor sources are also important to consider. Movement of people re-suspends the dust settled on the surface and thereby increases the PM levels. In our case, it has to be mentioned that due to strike of janitorial staff, cleaning activities were quite irregular and not up to the normal standards. A visible impact of the strike was recorded in our results as the average levels of $PM_{2.5}$ are observed to increase from ward to ward. The medical ward was monitored first and the PM levels are lower as compared to the nephrology ward (78 vs 488 $\mu g/m^3$). Although cleaning activities re-suspend the settled particles, it is a temporary process as most of the particles are swept away in the cleaning activity. On the other hand, irregular cleaning and floor sweeping results in more deposition of particles than are cleared. As observed in this research, as the cleaning activities decreased over time, PM levels increased considerably. The deposited dust was re-suspended again and again due to movement of people as there was no removal process.

In addition the results show that outdoor concentrations of $PM_{2.5}$ were above accepted air quality standards and indicate that site is highly affected by heavy traffic. Indoor levels were generally higher than the corresponding outdoor, bar surgical and paediatric wards. This is most probably due to presence of indoor aerosol sources such as people movement/activities, sweeping, and poor ventilation. In the urban environment there are many sources for particulate matter such as

traffic and industry (Wehner *et al.* 2002, Hussein *et al.* 2005, and Arnold *et al.* 2006). These may lead to elevated indoor concentrations by ambient air penetration in the indoor microenvironments (Diapouli *et al.* 2011).

Conclusion: The study demonstrated that aerosol particles are frequently liberated within the wards. The high I/O ratios observed in the wards and ambient air reveals greater contribution from indoor sources to PM. Pakistan, being a developing country, is confronting serious problems in the health sector and lacks strategies to maintain air quality in the healthcare environments. The outcomes of the study illustrates that the particulate matter levels imparted by various indoor activities and infiltration from outdoor can be used as a tool in determining air quality of the healthcare environments.

REFERENCES

- Abt, E., H. S. Helen, A. George and K. Petros (2000). Characterization of Indoor Particle Sources: A Study Conducted in the Metropolitan Boston Area. *Environ. Health Persp* 108: 35-44
- Arnold F., I. Irjola, H. Aufmhoff, T. Schuck, T. Lahde and K. Hameri (2006). First gaseous sulfuric acid measurements in automobile exhaust: Implications for volatile nanoparticle formation. *Atmos. Environ.* 40: 7097-7105
- Bernards, A. T., H. M. Frénay, B.T. Lim, W.D. Hendriks, L. Dijkshoorn and C.P. Van Boven (1998). Methicillin-resistant *Staphylococcus aureus* and *Acinetobacter baumannii*: an unexpected

- difference in epidemiologic behavior. *American J. Infection Control*. 26(6): 544-551.
- Charkowska, A. (2008). Ensuring Cleanliness in Operating Theatres. (*JOSE*) 14(4): 447-453.
- Diapouli, E., K. Eleftheriadis, A.A. Karanasiou, S. Vratolis, O. Hermansen, I. Colbeck and M. Lazaridis (2011). Indoor and Outdoor Particle Number and Mass Concentrations in Athens. Sources, Sinks and Variability of Aerosol Parameters *Aerosol and Air Quality Research*, 11: 632-642
- Hussein T., K. Hameri, P. Aalto, A. Asmi, I. Kakko and M. Kulmala (2004). Particle size characterization and the indoor-to-outdoor relationship of atmospheric aerosols in Helsinki. *J. Work environ. Health* 30: 54-62.
- Kumari, D. N. P., T.C. Haji, V. Keer, P.M. Hawkey, V. Duncanson and E. Flower(1998). Ventilation grilles as a potential source of methicillin-resistant *Staphylococcus aureus* causing an outbreak in an orthopaedic ward at a district general hospital. *J. Hospital Infection*, 39(2): 127-133.
- Nitta H., M. Ichikawa, M. Sato, S. Konishi and M. Ono (1994). A new approach based on a covariance structure model to source apportionment of indoor fine particles in Tokyo, *atmos. Res.*, 28: 631-636.
- Pope, C.A., D.V. Bates, and M.E. Raizenne (1995). Health effects of particulate air pollution: time for reassessment? *Environ. Hlth. Perspect.* 103: 472-480.
- Saksena,S and R.Uma (2008). Longitudinal study of indoor particulate matter and its relationship to outdoor concentrations in New Delhi, India. *Indoor and built environment*. 17 (6): 543-551.
- Uduman, S. A., A.S. Farrukh, K.N.R. Nath, M.Y.H. Zuhair, A. Ifrah, A.D. Khawla and P. Sunita (2002). An outbreak of *Serratia marcescens* infection in a special-care baby unit of a community hospital in United Arab Emirates: the importance of the air conditioner duct as a nosocomial reservoir. *J. Hospital Infection*. 52(3): 175-180.
- Wehner B., W. Birmili, T. Gnack and A. Wiedensohler (2002). Particles number size distribution in a street canyon and their transformation into the urban air background: measurements and a simple model study. *Atmos. Environ.* 36:2215-2223.
- WHO. (2011). Report on the burden of endemic healthcare-associated infection worldwide, *Clean Care is Safer Care*, A systematic review of the literature, World Health Organization, 20 Avenue Appia, 1211Geneva 27, Switzerland.